This microfiche was produced according to ANSI / AIIM Standards and meets the quality specifications contained therein. A poor blowback image is the result of the characteristics of the original document.

NASA Technical Memorandum 107044

p. 11

ACTS On-Orbit Multibeam Antenna Pattern Measurements

R. Acosta, D. Wright, and F. Regier
Lewis Research Center
Cleveland, Ohio

September 1995

National Aeronautics and
Space Administration

ACTS ON-ORBIT MULTIBEAM ANTENNA PATTERN MEASUREMENTS

R. Acosta, D. Wright and F. Regier

NASA Lewis Research Center
21000 Brookpark Rd.
Cleveland, Ohio

ABSTRACT

The Advanced Communication Technology Satellite (ACTS) is a key to reaching NASA's goal of developing high-risk, advanced communications technology using multiple frequency bands to support the nation's future communication needs. Using the multiple, dynamic hopping spot beams and advanced on board switching and processing systems, ACTS will open a new era in communications satellite technology. One of the key technologies to be validated as part of the ACTS program is the multibeam antenna (MBA) with rapidly reconfigurable hopping and fixed spot beams to serve users equipped with small-aperture terminals within the coverage areas. The MBA test program is designed to evaluate the on-orbit ACTS antenna performance. The main parameters measured are beam shape, beam center location and gain.

INTRODUCTION

The on-orbit measurements of the ACTS MBA antenna patterns (TX and RX) have an advantage over pre-flight ground antenna range data because on-orbit measurements are made in the far-field zone, and will include post launch effects, such as reflector deployment errors, thermal effects and spacecraft attitude errors [1]. Unlike usual near-field measurements for which the object of the test is readily accessible, during on-orbit testing the spacecraft is i geosynchronous orbit approximately 36,000 km away from the earth station from which the test is performed. Hence, the test setup calibration must take into account not only the earth station equipment and ant na, but also the RF path between the station and the spacecraft. The signal attenuation between these two antennas, however, is not constant but varies according to the atmospheric conditions. Consequently, testing procedures have been devised so that most of the measurements are relative and self-consistent.

The technical objective of the ACTS MBA on-orbit test program is to determine the post launch (on-orbit) transmit and receive antenna performance (beam shape, beam center and gain). Multiple antenna far-field pattern (co pol and cross pol) cuts are obtained by maneuvering the ACTS spacecraft using the momentum wheel mechanism (pitch axis, east-west rotations) and the magnetic torquers (roll axis, north-south rotations) on board the spacecraft. This is, in principle, similar to performing a routine far-field antenna test.

THE MULTIBEAM ANTENNA

The ACTS MBA consists of two offset Cassegrain antennas (see figure 1), one transmit and one receive, and an antenna support assembly [2,3]. The two antennas are nearly identical electrically, with the larger 20 GHz transmit main reflector having a diameter of 3.3 m and the smaller 30GHz receive reflector a diameter of 2.2m. Aside from a common antenna support assembly, each antenna consists of three major sections: a main reflector, an assembly consisting of one front and one back subreflector, and a pair of feed assemblies, one having horizontal, and the other vertical, polarization.

Because of its high strength, light weight, and low coefficient of thermal expansion, graphite epoxy finds wide use in the MBA. The entire MBA weighs about 900 lb with the antenna support assembly, fabricated from graphite epoxy tubes with titanium fittings, making up about half this weight.

ACTS utilizes the frequency ranges 29.0 to 30.0 GHz uplink and 19.2 to 20.2 GHz downlink. Re-use of the same frequency band without interference is made possible, in some cases by spatial separation of low-sidelobe beams, and in other cases, where beams need to be in close proximity, by the use of orthogonal polarizations.

ACTS is an experimental prototype of an operational communications system and incorporates three different types of beam: 3 fixed or trunking beams, 13 switched spot beams, and 34 switched triplet spot beams. The trunking beams, which usually operate in conjunction with the microwave switch matrix, achieve isolation through spatial separation. The triplet and spot beams normally operate in conjunction with the baseband processor and are designed to provide continuous coverage of two adjacent scan areas constituting about 20 percent of the area of the continental U.S., as well as additional isolated metropolitan areas. The geographical coverage of ACTS MBA is shown in figure 2.

The use of spot beams makes possible antenna gains about 20dB higher than would be possible for a single beam covering the continental U.S. In the scan areas and between scan spots, beams are switched by switching feed horns. In the case of continuous coverage areas, triangular triplets consisting of three feed horns are used, and one horn may at different times be a constituent of more than one beam location.

Because the transmit and receive antennas are offset from the spacecraft in opposite senses, transmit and receive antenna patterns, though similar, are not identical.

Scanning away from boresight causes some gain loss- about 2 dB for West Coast beams.

TEST TECHNIQUES

Rx Beam Optimization:

The pitch and roll biases on the attitude control system (ACS) are used to rotate the spacecraft east-west and north-south from its nominal position to determine the optimal pitch and roll bias settings for the receive antenna, utilizing the Cleveland fixed beam as the reference. The spacecraft can be rotated in increments of 0.01 degrees up to +/- 0.12 degrees along both axis. The spacecraft received power from NASA ground station is measured and monitored (by telemetry) as functions of pitch and roll.

TX Beam Optimization:

The transmit antenna can be optimized after the receive antenna optimization procedure is accomplished. The transmit antenna pointing can be optimized by adjusting the biax drive motor which will rotate the transmit main reflector in two axes (north-south and east-west). The procedure is performed until co-alignment is achieved between the Cleveland fixed transmit and the Cleveland fixed receive beam. This task is accomplished by recording the downlink power received at Cleveland ground station as a function of main reflector pitch and roll. The TX main reflector is rotated in increments of 0.01 degree up to +/-0.15 degrees.

Transmit and Receive Beam Shape:

After the RX and TX antenna beam optimization procedure has been performed, the spacecraft can be rotated in pitch and roll for antenna beam shape measurements. The spacecraft is rotated in increments of 0.02 degrees up to +/- 1 degrees in pitch and roll. (see figure 3).

The transmit beam shape pattern measurements are performed independently of the uplink (receive) pattern measurements. The downlink signal is internally generated in the ACTS spacecraft and does not depend on the uplink signal. The downlink signal is recorded at ground station as a function of pitch and roll angles.

The uplink signal originates at the NASA ground station and is measured at the spacecraft input. This signal is measured and its value transmitted in a downlink telemetry channel and recorded as a function of spacecraft rotation angles.

Transmit and Receive Beam Centers:

The test procedure for measuring beam centers consists in establishing a two-way data link between the Cleveland ground station (Using West Scan 08 beam) and a T1-VSAT station located in the beam that is under test (see figure 4) . Received power is measured indirectly by measuring bit error rate (BER). Bit error test sets are required for measuring and monitoring the antenna performance downlink and uplink at both locations, the NASA ground station and at the T1-VSAT. The BER's are recorded as a function of spacecraft rotation in pitch and roll. The NASA ground station does not introduce any errors in this procedure since it has very large gain margins in both uplink and downlink.

SPACECRAFT MANEUVERS

During the various test procedures, the spacecraft may make use of either of two different orientation-sensing systems.

These are:

(i) Autotrack System, the spacecraft rotates in pitch and roll in increments of 0.01 degrees with a dynamic range of +/- 0.12 degrees.

(ii) Earth Sensor System, the spacecraft rotates in pitch and roll in increments of 0.02 degrees with a dynamic range of at least +/- 1.0 degrees.

Both systems directly control the momentum wheels assemblies (east-west/pitch) and magnetic torquers (north-south/roll) of the spacecraft attitude control system, providing the capability of rotating the spacecraft in the desired directions.

SOURCES OF ERROR

The on-orbit MBA antenna tests are subject to same type of error sources as more conventional near-field measurements. There are the uncertainties due to ground-station performance (such as gain, transmission power, receiver instabilities and polarization purity), to misalignments (such as satellite and ground station pointing errors) and those due to uncertainties in satellite RF performances (such as receiver noise figure, TWTA output-power level, etc.)

Propagation effects, are compensated based on measurements of received beacon power.

The satellite movement with respect to earth as a function of time is also a source of error. Although this movement is small (less that 0.1 degree it can still have significant effect on the measurements. A correcting factor can be found from the knowledge of the satellite's orbit and the ground-station antenna pattern. The satellite pointing instabilities are another source of error. Taking measurements over a long period to be able to average out such a variation would take too long, and so the best that can be done is to try to correct the results, when necessary, based on the telemetred information from the satellite attitude sensors.

CONCLUSIONS

A total of 10 different antenna pattern cuts (Beam Shape and Beam Center) were taken. These beam patterns represent all relevant beam combinations (TX west and east, RX west and east) in the ACTS MBA. The on-orbit antenna patterns closely match the pre-flight measurements from near-field range. Typical transmit antenna patterns from ACTS MBA are shown in figures 5a,5b,5c and 5d, which include both the on-orbit measured points and the values predicted from pre-flight measurements. Figure 6a,6b,6c,6d present a typical beam center test, which include data from the BER test sets located at the T1-VSAT and its NASA ground station. Table I presents in tabulated form, all beam centers measured. The on-orbit beam centers are no worse than the pre-flight measured beam centers. This is a very good indication that MBA performance is well within the expected range, and that TX and RX beam optimization procedures were successfully executed. In general, the on-orbit MBA measurements have shown that all design parameters have been met and that excellent pointing performance has been achieved.

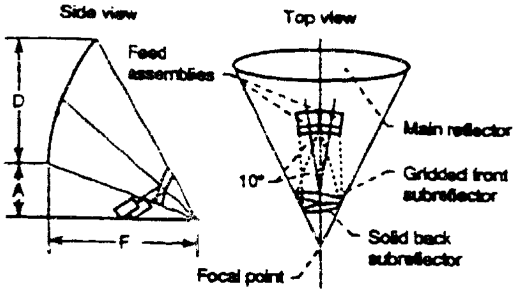
Currently we are investigating thermal distortion effects on the ACTS MBA performance as a function of time and season. The effects of thermal distortion are necessary to complete the assessment of the ACTS MBA.

REFERENCES

(1) Acosta, R.; Larko, J.; and Lagin, A.: Advanced Communication Technology Satellite (ACTS) Multibeam Antenna Technology Verification Experiments. **NASA Technical Memorandum 105421, July 1992.**

(2) Regier, F.: The ACTS Multibeam Antenna. NASA **Technical Memorandum 106645, April 1992.**

(3) Acosta, R.;J. Larko; Narvaez, A.; and A. Lagin: Advanced Communication Technology Satellite (ACTS) Multibeam Antenna Analysis and Experiment. **NASA Technical Memorandum 105420, July 1992.**



Parameter	20 GHz	30 GHz
D (Main reflectordiameter, inches)	129.9	86.6
A (Offset distance, inches)	50.0	44.0
F (Main reflector focal length, inches)	132.0	88.0
Gridded front subreflector		
Focal length, inches	69.0	44.5
Magnification factor	2.0	2.0
Solid back subreflector		
Focal length, inches	52.4	32.4
Magnification factor	2.0	2.0

Figure 1.- ACTS Multibeam Antenna Geometry.

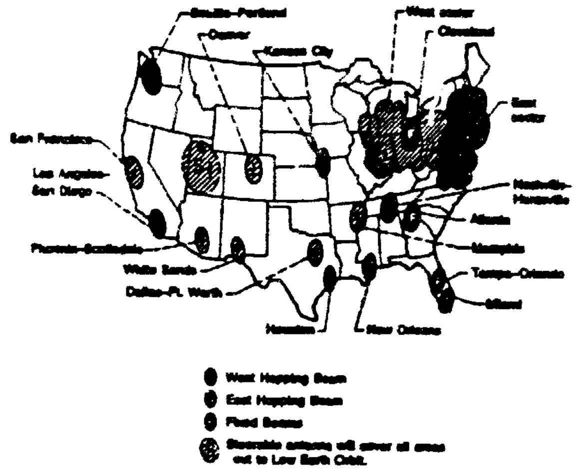


Figure 2.- Geographical coverage of ACTS Multibeam Antenna.

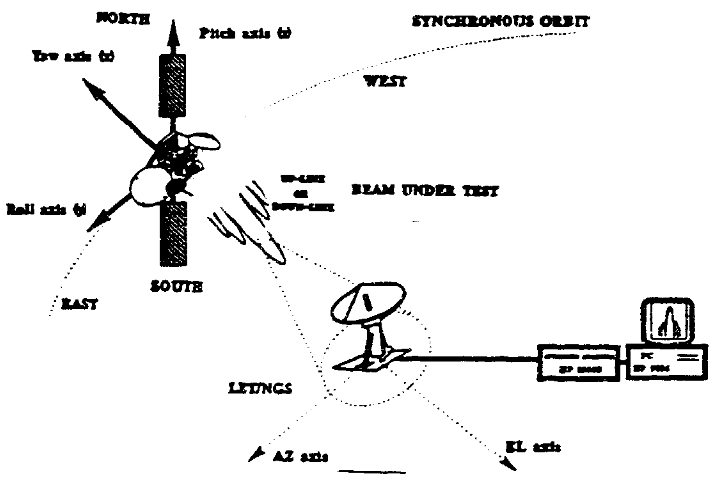


Figure 3.-In-orbit antenna beam shape measurements.

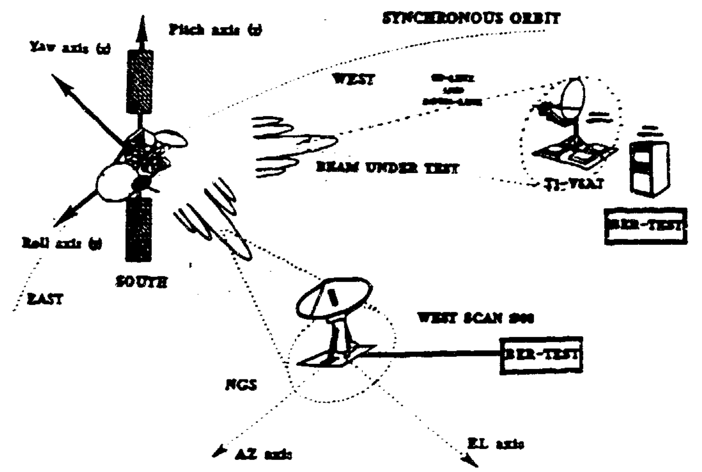


Figure 4.-In-orbit antenna beam pointing measurements.

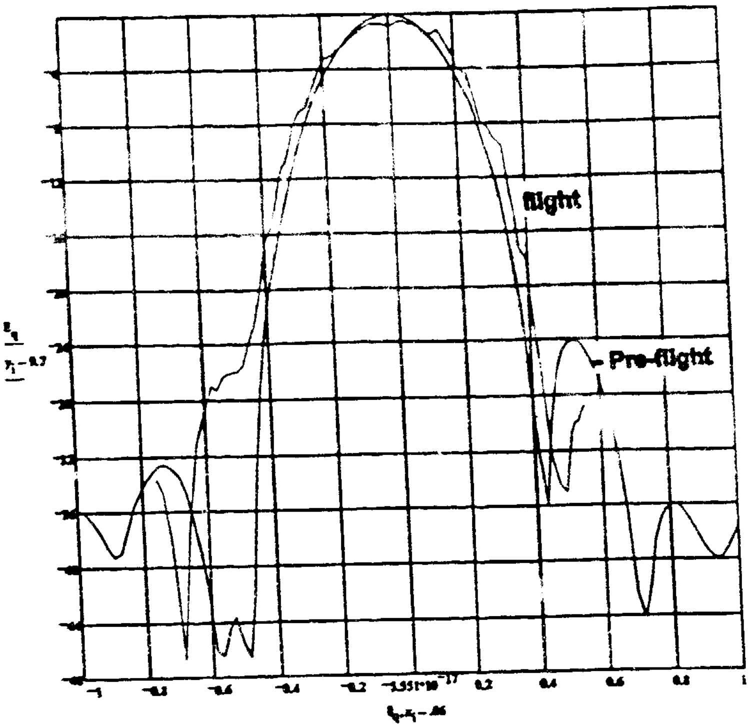


Figure 5a.- Pre-flight vs. flight roll antenna pattern (Cleveland fixed TX)

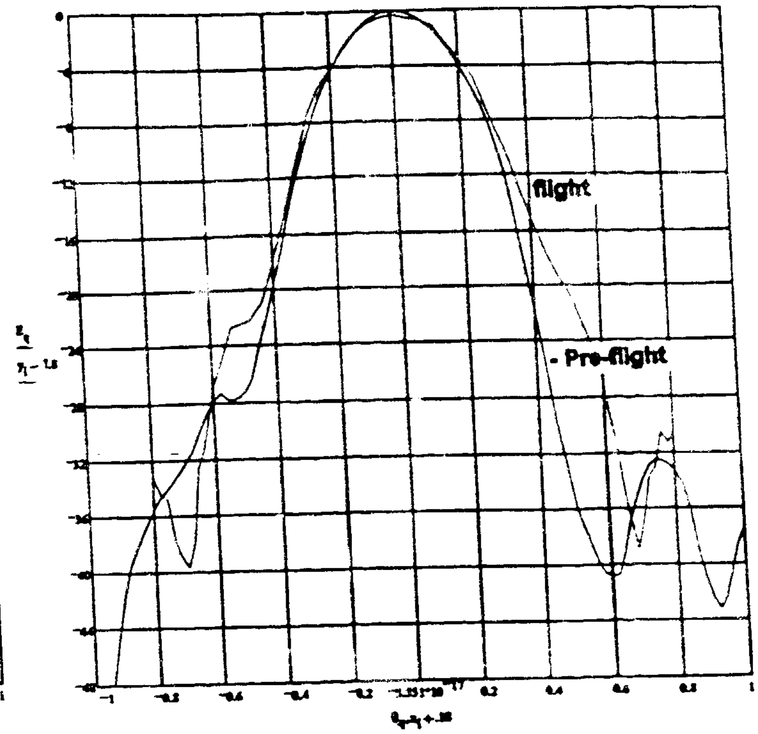


Figure 5b.- Pre-flight vs. flight pitch antenna patterns (Cleveland Fixed TX)

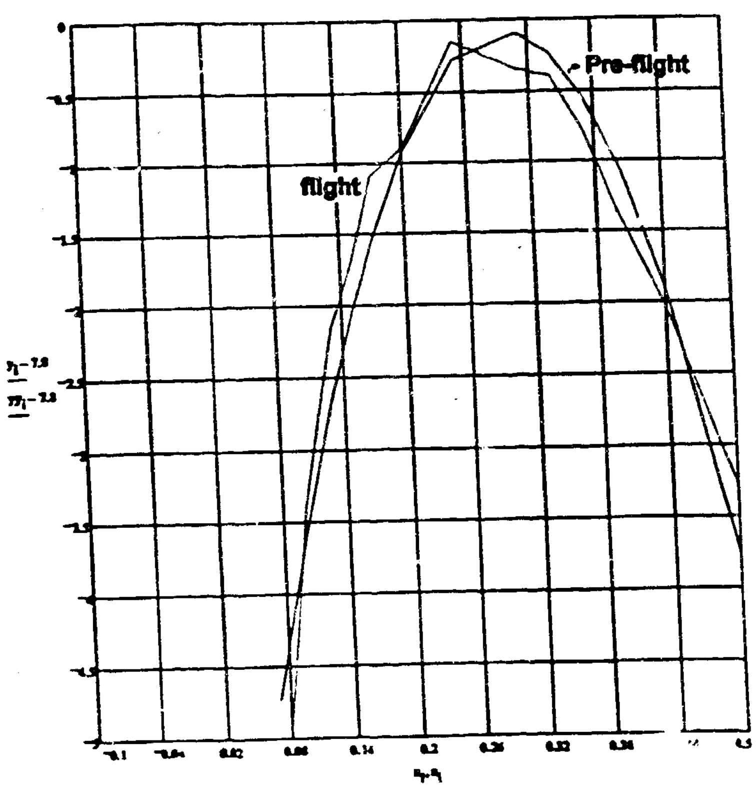


Figure 5c.- Pre-flight vs flight roll antenna pattern (East Scan 07 TX)

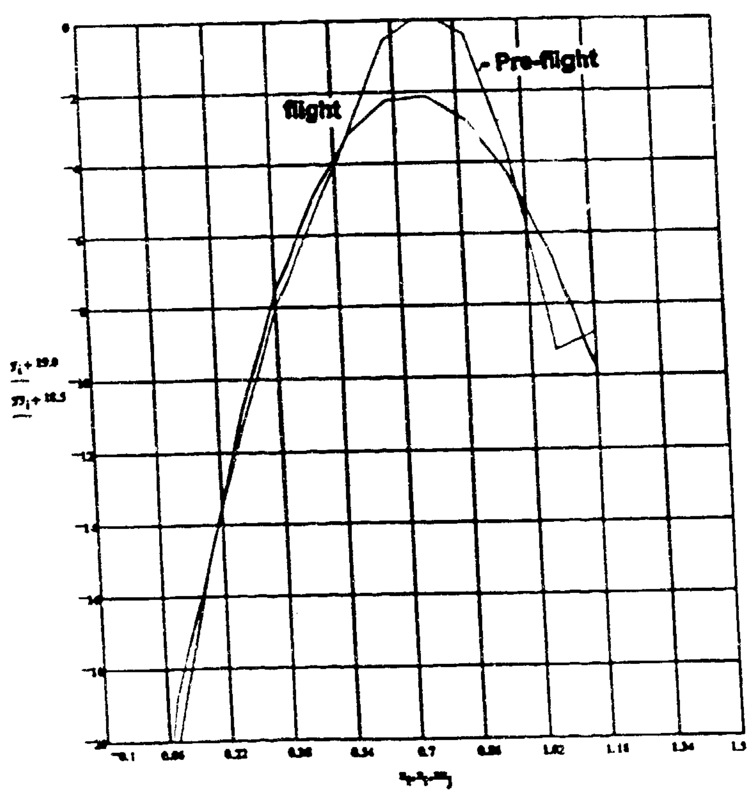


Figure 5d.- Pre-flight vs. flight pitch antenna pattern (East Scan 07 TX)

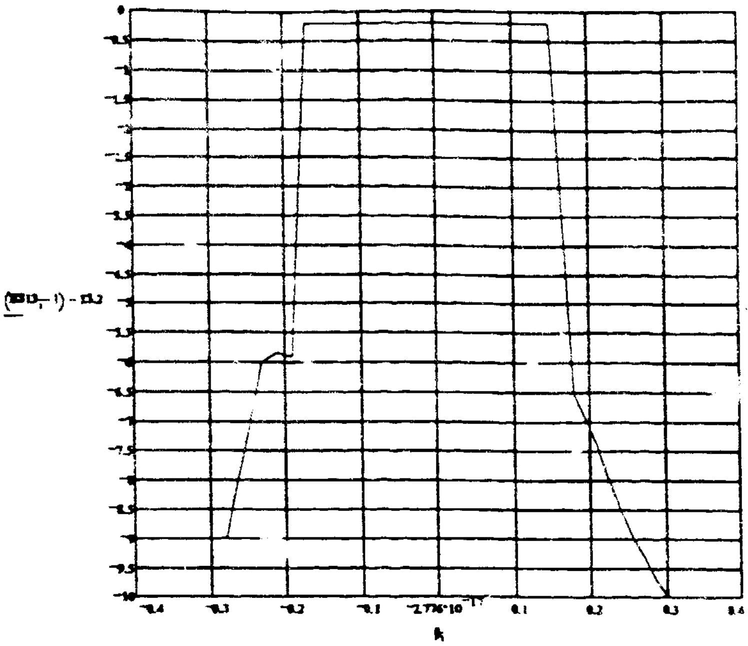


Figure 6a.- Flight RX BER vs. roll angle
(West Phoenix)

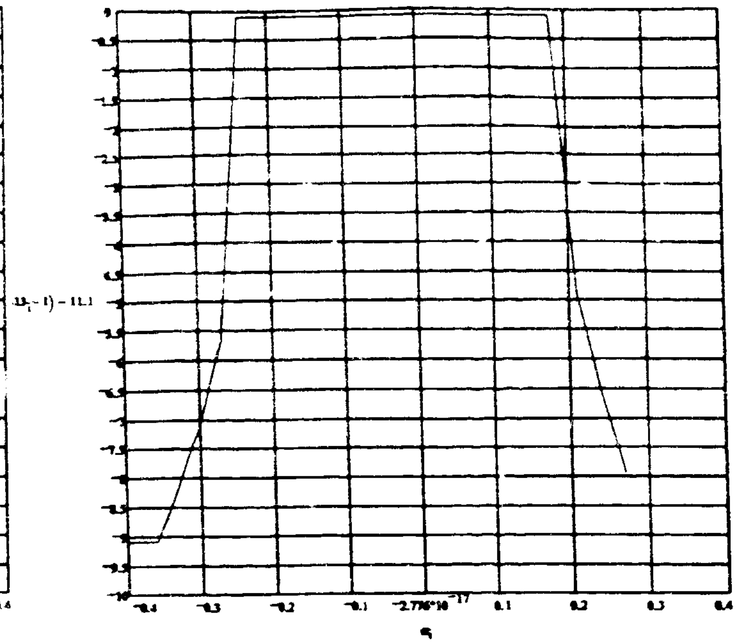


Figure 6b.- Flight RX BER vs. pitch angle
(West Phoenix)

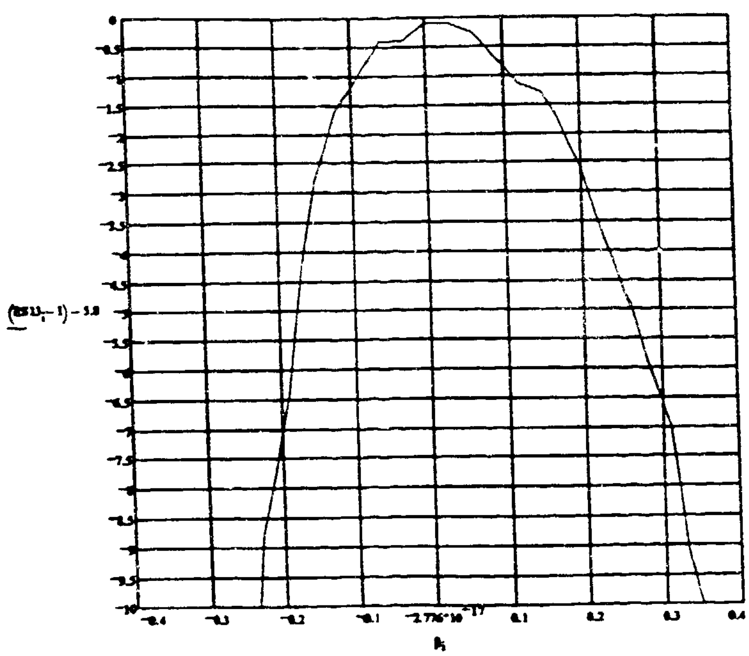


Figure 6c.- Flight TX Eb/n0 vs. roll angle
(West Phoenix)

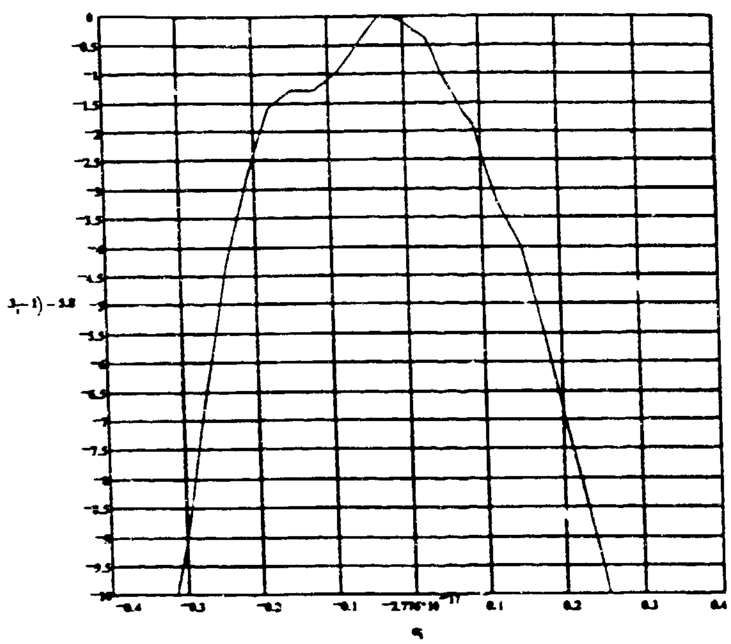


Figure 6d.- Flight TX Eb/n0 vs pitch angle
(West Phoenix)

TABLE I : BEAM CENTER DIFFERENTIAL (TX-RX)
Pre-Flight vs Flight

EARTH STATION ID	BEAM ID	Pre-Flight Roll (TX-RX)	Pre-Flight Pitch (TX-RX)	Flight Roll (TX-RX)	Flight Pitch (TX-RX)
ES03	WS[illegible]	−0.024	+0.044	+0.0[illegible]0	n.a.
ES09	E. DENVER	−0.035	+0.036	n.a.	−0.030
ES11	WS17	−0.027	+0.070	+0.020	−0.010
ES12	W. Houston	−0.057	+0.064	+0.010	−0.010
ES13	W. Phoenix	−0.026	+0.038	+0.060	−0.010
ES04	E. LA	−0.025	+0.061	n.a.	−0.030
ES14	E1	−0.017	+0.100	n.a.	−0.060
LET	E. Clev	−0.040	+0.060	+0.060	−0.040

n.a. = not available

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
September 1995

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
ACTS On-Orbit Multibeam Antenna Pattern Measurements

5. FUNDING NUMBERS
WU-679-40-00

6. AUTHOR(S)
R. Acosta, D. Wright, and F. Regier

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135-3191

8. PERFORMING ORGANIZATION REPORT NUMBER
E-9879

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, D.C. 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA TM-107044

11. SUPPLEMENTARY NOTES
Responsible person, R. Acosta, organization code 6120, (216) 433-6640.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 32

This publication is available from the NASA Center for Aerospace Information, (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Advanced Communication Technology (ACTS) is a key to reaching NASA's goal of developing high-risk, advanced communications technology using multiple frequency bands to support the nation's future communication needs. Using the multiple, dynamic hopping spot beams and advanced on board switching and processing systems, ACTS will open a new era in communications satellite technology. One of the key technologies to be validated as part of the ACTS program is the multibeam antenna (MBA) with rapidly reconfigurable hopping and fixed spot beams to serve users equipped with small-aperture terminals within the coverage areas. The MBA test program is designed to evaluate the on-orbit ACTS antenna performance. The main parameters measured are beam shape, beam center location and gain.

14. SUBJECT TERMS
Space communications; Ka-band; Antennas; Multibeam antennas

15. NUMBER OF PAGES
11

16. PRICE CODE
A03

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

END

DATE

FILMED

OCT 31 1995

AIIM

Association for Information and Image Management

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS

BY APPLIED IMAGE, INC.